International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 08, August-2015

Seismic Analysis of Multi-Storey Frames using Chevron Bracings

Dr. V. Devaraj
Professor
Department of Civil Engineering
UVCE, Jynana Bharathi Campus
Bangalore-560056

Mrs. Thejaswini. R. M
Assistant Professor
Department of Civil Engineering
Govt S.K.S.J.T.I, K.R.Circle
Bangalore-560001

Usha. K. N
M.Tech student
Structural Engineering
Govt S.K.S.J.T.I, K.R.Circle
Bangalore-560001

Abstract **- The models of multi storey steel structure with Chevron and Inverted V bracings having same geometry except a link beam in Chevron system between mid-span of beam and braces are studied. Models are developed using E-tabs software as per codal provision of IS 800: 2007. These models are analyzed using Response Spectrum method as per IS 1893(Part I): 2002.The Brace forces, Storey Displacement, Vertical Displacement of Beams, Drift Index are tabulated, graphs are plotted and compared. From results of the considered parameters, Chevron with 0.25m link beam has showed better performance compared to other Chevron bracings with different link beams and the chance of failure of beam is less in Chevron bracing system compared to Inverted V bracing system. The best type of arrangement of Chevron bracing with 0.25m link beam is studied.**

Key words: Chevron Bracings, Inverted V Bracings, Link Beam, Brace Forces, Displacement, Drift Index.

I. INTRODUCTION

In developing countries like India, urbanization started with industrialization which creates the people to migrate to urban sectors, this caused the scarcity of land and therefore there has been considerable increase in construction of multi-storey structures.

Modern trend is towards the structures built out of steel or composite steel compared to R.C.C since steel has high strength & ductility. For a structure there will be two types of loads acting on it i.e. vertical and horizontal loads. Vertical loads are gravity loads; horizontal loads are live load whose main component is horizontal force acting on the structure eg:- wind load, an earthquake and the earth pressure against a retaining wall. For Structure to be safe enough; it should have a capacity to resist horizontal forces along with the gravity loads. To resist lateral loads various structural forms are evolved such as Shear Wall system, Frame Tube system, Outrigger system, Bundled Tube system, Bracing system etc...

1.1 **Bracing system** is one of the structural forms which form the integral part of the frame. It provides stiffness to the frame and mitigates lateral drift of the structure due to lateral force. It is considered as the most efficient, economical and effective system in resisting lateral force.

Bracing system can be classified into two types

(1) ***Concentrically Braced Frames (CBFs):*** are those braced frames in which the centre lines of the bracing members meet at the main joints in the structure, thus minimizing residual moments in the frame. At low cost CBFs provide strength and stiffness but ductility is limited and these types of bracings will restrict architectural planning. Eg: X-braced, Single diagonal brace, V type, Inverted V type and K-braced.

(2) ***Eccentrically Braced Frames (EBFs):*** are those systems in which the braces are not concentric with the beam and column joints but they are separated eccentrically. They provide strength and stiffness of a braced frame with the inelastic behavior and energy dissipation characteristics of a moment frame. They are designed to control frame deformations and to minimize the architectural finishes. EBFs are lighter and ductile in nature compared to CBFs. A common example of Eccentrically Braced Frame is Knee bracing system.

1.2 Inverted V Bracing and Chevron Bracings with Link Beam

In Inverted V Bracing

In Inverted V Bracing beam is supported at mid-span forming a vertical truss system to resist lateral forces. Depending on the direction of lateral load one brace will be under compression and other brace will be under tension as shown in figure 1. These braces resists lateral load axially and do not carry any vertical loads. on continuous application of lateral load the compression brace buckles due to which its compression capacity decreases leads to buckling of brace and hence plastic hinge will be formed at the mid-span of the beam before yielding of tension brace, therefore beams are pulled downward since both gravity load and tension force are acting together on the beam as shown in figure 2. Hence leads to failure of frame which is unacceptable. In order to prevent this deterioration of lateral strength of the frame, the beam has to possess adequate strength to resist this potentially significant post-buckling force redistribution in addition with gravity loads. Hence it requires very strong beams much than would be required for ordinary loads.

Chevron bracing system with link beam

It consists of Inverted V brace with a link beam connected between brace and a beam. Here also the braces will resists lateral load axially. The braces will be under tension or compression depending on the direction of lateral force as in case of Inverted V brace. The link beam (figure 3) is designed in such a way that, it acts as a fuse between brace and the beam. On continuous application of lateral load the buckling of brace is avoided to some extent and before buckling of compression brace link beam will fails so that the load from the yielding brace to beam is avoided.

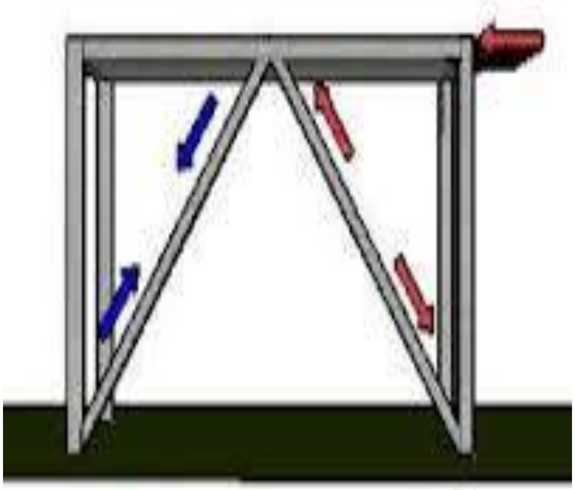


Figure 1: lateral load acing on Inverted V brace

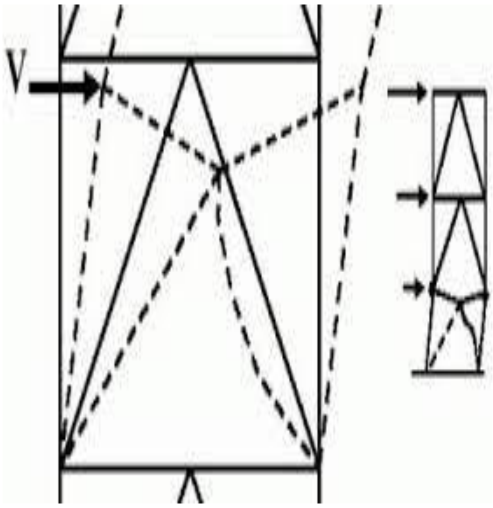


Figure 2: Buckling Of Inverted V Brace

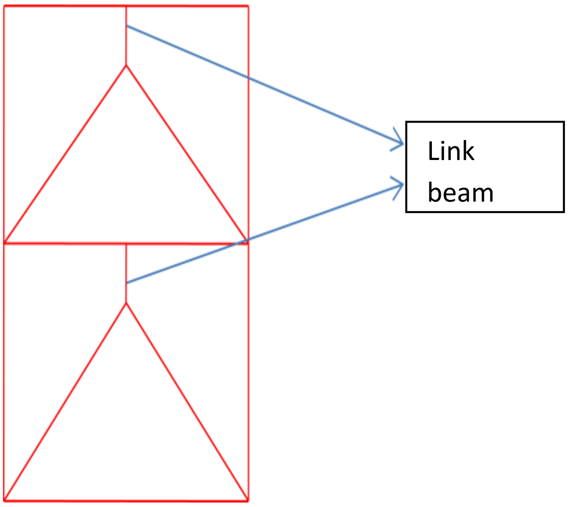


Figure 3: Chevron Brace

II. OBJECTIVE AND MODEL DISCRIPTION

A. Scope of the work

1. To develop one bay frame of 2D model Inverted V and Chevron bracing with link beam using E-Tabs software.
2. Static analysis is adopted to analyze the Bracing systems.
3. Evaluating the results from analysis and compared the axial forces acting on braces and on horizontal beam on both the system.
4. To develop 3D model of steel frame of Inverted 'V' braced and Chevron bracing with different lengths of link beam.
5. Comparing the results of three 3D models with respect vertical forces, storey displacement, vertical displacement of beam, inter-storey drift.
6. Various patterns of arrangements of Chevron brace are analyzed.

B. Preliminary Data of the Model

Table 1: Data of Dead and Live Loads [As per IS875 (Part I and II):1987]

Parapet wall load on beams	8.5 KN/m
Wall load on beams	17 KN/m
Floor finish + water proofing @ roof	2 KN/m^2
Floor finish @ floor	1 KN/m^2
Live load @ roof	1.5 KN/m^2
Live load @ floor	4 KN/m^2

Table 2: Earthquake Load Parameters [As per IS1893 (Part I):2002]

Zone, zone factor Z	V, 0.36
Importance factor, I	5
Soil type	II
Response reduction factor R	5
Percentage of imposed load considered	50%
Damping ratio	0.05
Eccentric ratio	0.05
Time period	0.342, 0.3838 (X,Y)
Number of modes	12
Method of Analysis	Response Spectrum Analysis
Modal Combination	SRSS Method (Square root of the Sum of the Squares)

C. Model Description

To study the behavior of Chevron bracing, a 3 storey one bay two dimensional frame has been generated and checked the results with the Inverted V brace frame for the applied equivalent horizontal load in ratios. Later a three dimensional commercial steel structure with 4 bays of 5m along X-axis, 3 bays of 4m along Y-axis and 5 number of stories is considered. The columns and beams are designed according to IS 800:2007code. Vertical loads are to be applied on the building are considered as per IS 875:1987 (part 1 & 2). The lateral loads are chosen as per Indian standards, the study is carried out for seismic zone V as per IS1893:2002 (part 1). The frames are assumed to be rigid and firmly fixed to the soil.

Table 3: Data of 2D model

Structure	Steel moment resisting frame
Number of stories	3
Number of bays	1
Storey height	3m
Lateral force	Applied in ratios
Beam section	ISMB300
Column section	ISMB500
Braced section	ISMB200, ISMB175

Table 4: Data of 3D model

Structure	Steel moment resisting frame
Number of stories	5
Number of bays	4,3 (X,Y axes)
Storey height	3.5m & 3m @ base
Beam section	ISMB300, ISMB400
Column section	ISMB 500
Braced section	ISMB300, ISMB250

D. Models Considered

Figure 4: 2D Inverted V Brace frame

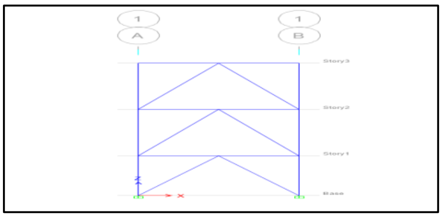
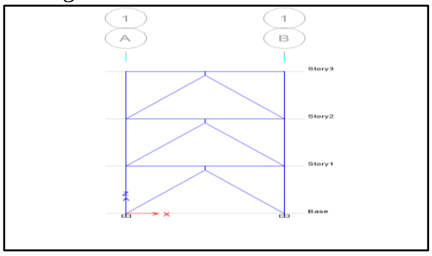


Figure 5: 2D Chevron Brace frame



3D MODELS

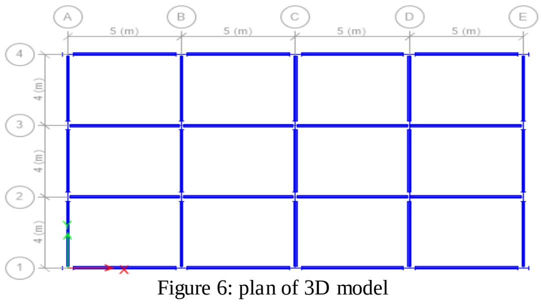


Figure 6: plan of 3D model

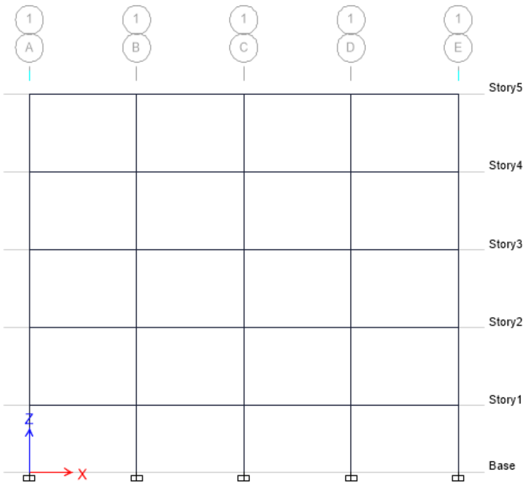


Figure 7: Unbraced Model

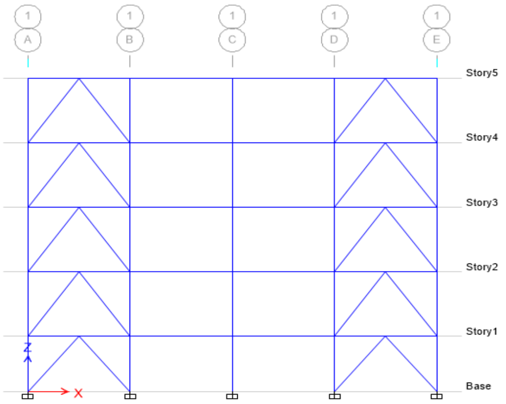


Figure 8: Inverted V Model

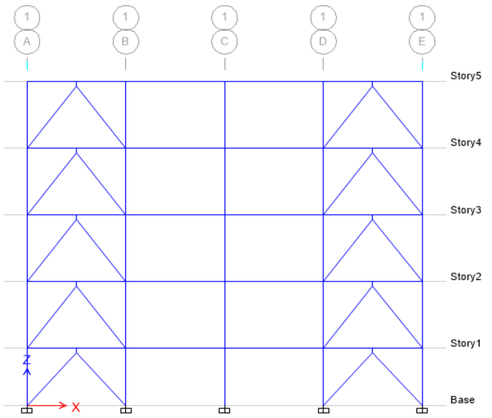


Figure 9: Chevron with 0. 25m link beam

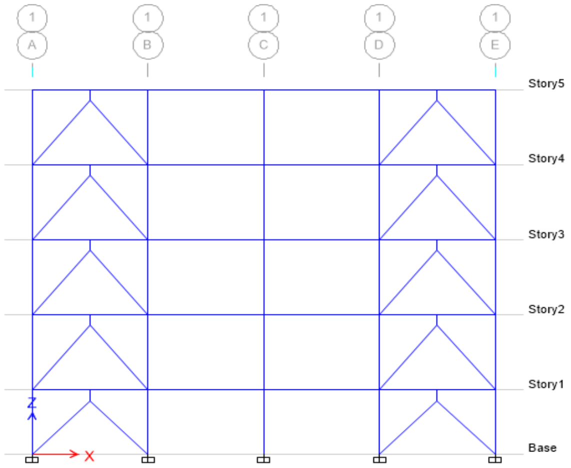


Figure 10: Chevron with 0. 5m link beam

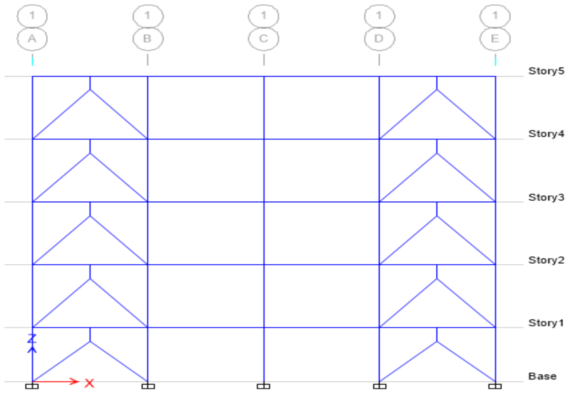


Figure 11: Chevron with 0.75m link beam

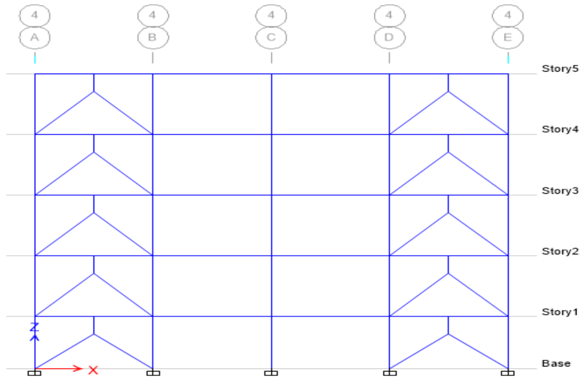


Figure 12: Chevron with 1m link beam

Different Arrangement Patterns of Chevron bracing of 0.25m link beam

Model 1

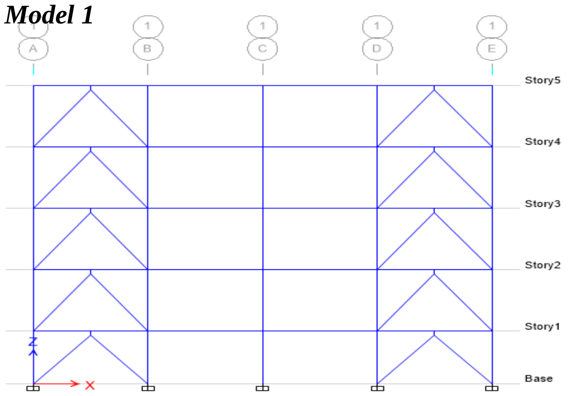


Figure 13: Bracings are arranged at the corners of the structure

Model 2:

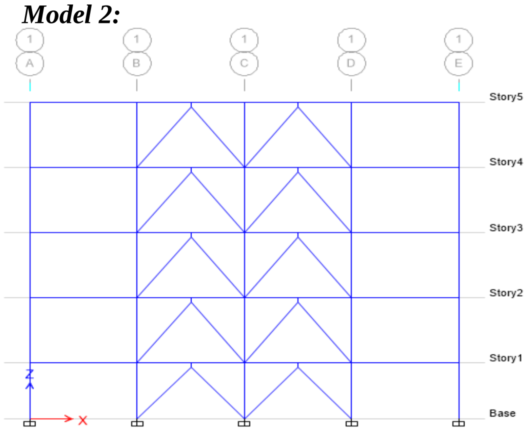


Figure 14: Bracings are arranged at the mid bays of the structure

Model 3

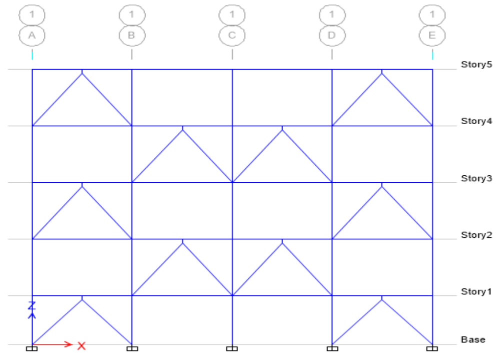


Figure 15: Bracings are arranged alternatively to the bays of the structure

Model 4:

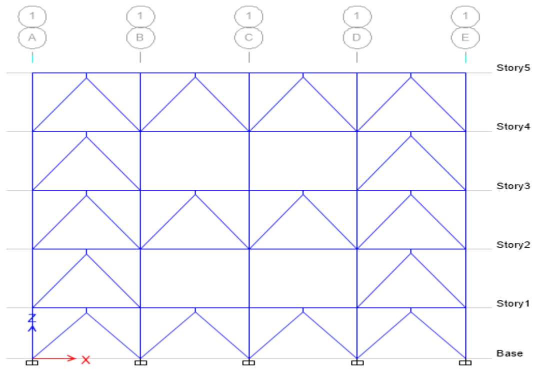


Figure 16: Bracings are arranged alternatively in central bays with respect to storey

Model 5:

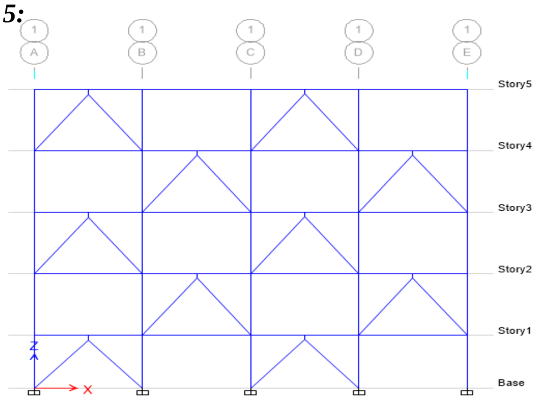


Figure 17: Bracings are arranged alternatively in all bays with respect to the storey

ISSN: 2278-0181
Vol. 4 Issue 08, August-2015

III. RESULTS AND DISCUSSION

A.Axial Loads Acting on Braces on 2D Frame

Here, the ratio of tension and compression load acting on Inverted V and Chevron bracings at storey 1 are tabulated for case 1, 2 & 7 and the buckling of compression brace is observed as shown in figures 13, 14, 15.

Table 5: Axial Loads Acting on Braces on 2D Frame

Equivalent lateral force	Tension	Compression
Case 1: 40KN	1 :0.89	1 : 0.84
Case 2: 50KN	1 : 0.91	1: 0.91
Case 7:100KN	1 : 0.84	1 : 0.86

Note: From case 3 to Case 6 there was no considerable change has been observed on buckling of compression brace in both Inverted V and Chevron bracing systems.

Failures of Inverted V and Chevron Brace for the above cases

Figure 18.1: Failures of Inverted V compression brace for case 1

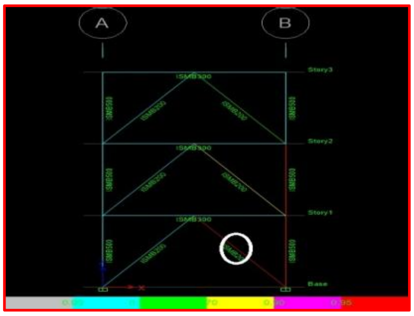


Figure 18.2: Failures of chevron brace for case 1

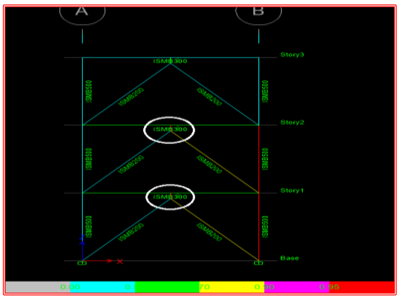


Figure 19.1: Failures of Inverted V compression brace for case 2

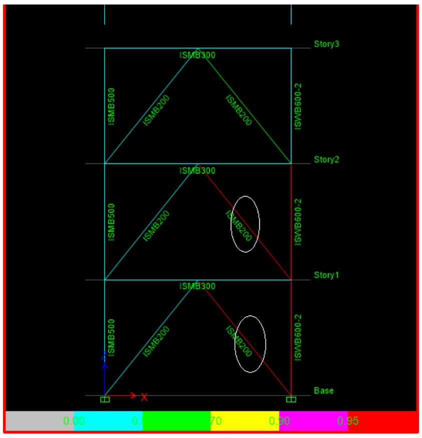


Figure 19.2: Failures of chevron brace for case 2

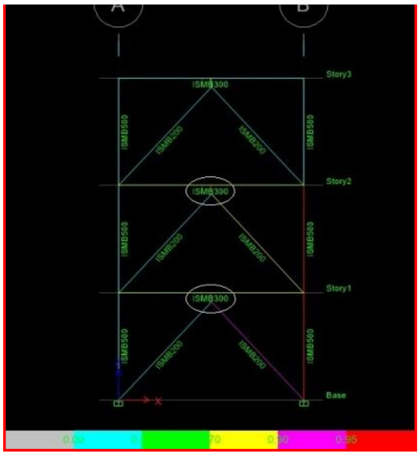


Figure 20.1: Failures of Inverted V brace for case 7

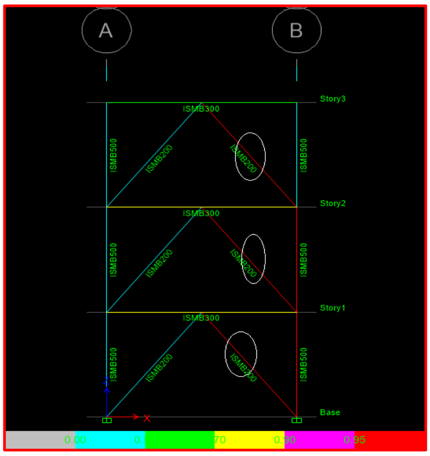
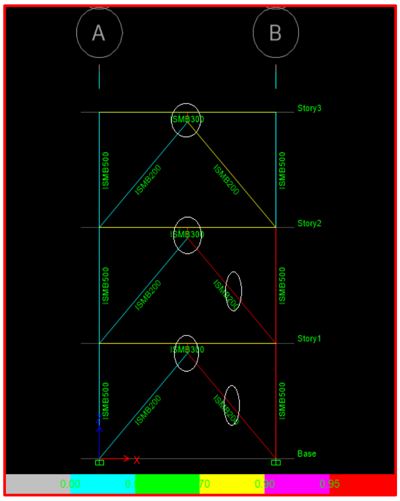


Figure 20.2: Failures of chevron brace for case 7



It is observed from the above tabulated results, about 84-91% of Inverted V compression and tension force is carried by Chevron Bracings. From the fig 18.1&18.2, for case 1 horizontal loading; a brace has buckled at storey 1 in Inverted V bracing and a link beam has failed at storey 1 and 2 in Chevron bracing.

For case 2 (fig19.1 & 19.2); compression brace has buckled at storey 1 & 2 in Inverted V bracing and only the link beam has failed at storey 1 and 2 in Chevron bracing.

For case 7 (fig20.1 & 20.2) horizontal loading; from the figure 14, it is observed that compression brace has buckled at all the storeys in Inverted V bracing and in Chevron bracing, the link beam has failed at storey 1, 2 and 3 and compression brace has buckled at storey 1 and 2.

B. AXIAL LOAD ACTING ON THE BEAM OF 2D FRAME

Axial load acting on beam is due to lateral force and the unbalanced load from the tension brace. The force acting on the beam for different load cases are as follows. The ratio of load acting on Beam of Inverted V bracing system to Chevron bracing system is tabulated

Table 6: Axial Load Acting On Beam

Equivalent lateral force	Ratio
Case 1: 40KN	1: 0.91
Case 2: 50KN	1: 0.91
Case 7:100KN	1: 0.91

From table 6, it is observed that the beams with Chevron bracings carries less axial load compared to those beams with Inverted V bracing. Up to 9% of axial load is avoided from brace to beam in Chevron bracing compared to Inverted V bracing.

RESULTS OF BRACING SYSTEMS FOR 5 STOREYS STEEL BULDING USING RESPONSE SPECTRUM METHOD

C. AXIAL FORCE IN BRACE

Here brace forces for earthquake load of bay 1AB and A12 along X and Y directions are calculated. The ratio of load carried by Inverted V and Chevron Bracing with different link beam lengths is tabulated in table 7.

From table 7, comparing Chevron bracings with different link beam lengths, Chevron with 0.25m link beam (Chev 0.25) has carried maximum of 91% tension and compression force carried by Inverted V brace for EQ X load case and 90%, 85% of tension and compression force for EQ Y load case. In Chevron bracings as the length of the link beam increased, force carried by brace has decreased i.e., CHEV 1m < CHEV 0.75m < CHEV 0.5m < CHEV 0.25m.

Table 7: Ratio of Load Carried by Chevron Brace Compared To Inverted V Brace

LOADS	TENSION		COMPRESSION	
	EQ X	EQ Y	EQ X	EQ Y
BAY	1AB	A12	1AB	A12
CHEV 0.25	1 : 0.91	1 : 0.90	1 : 0.91	1 : 0.85
CHEV 0.5	1 : 0.78	1 : 0.62	1 : 0.78	1 : 0.50
CHEV 0.75	1 : 0.63	1 : 0.40	1 : 0.63	1 : 0.13
CHEV 1	1 : 0.50	1 : 0.3	1 : 0.50	1 : 0.11

D. *STOREY DISPLACEMENT RESULTS*

Table 8: Storey displacement and its ratio of Inverted V and Chevron brace

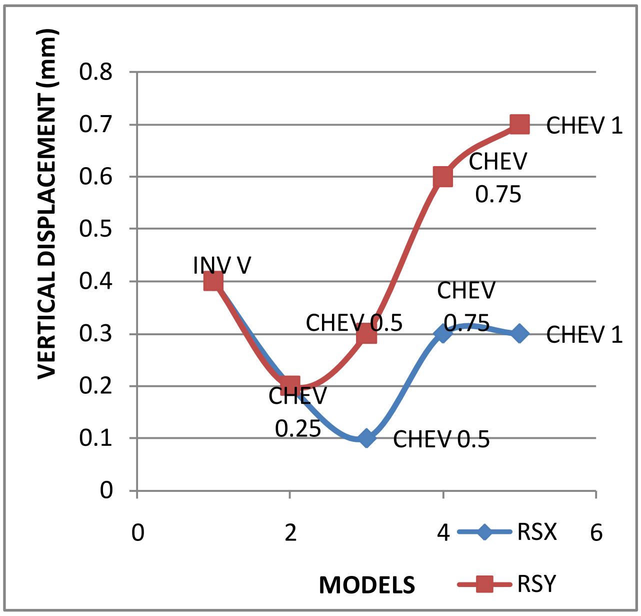
MODELS	RS X (mm)	RATIO	RS Y (mm)	RATIO
INV V	20.3		28.9	
CHEV 0.25	24.6	1 : 1.21	41.9	1 : 1.44
CHEV 0.5	34.3	1 : 1.69	86.7	1 : 3.00
CHEV 0.75	48.1	1 : 2.37	127	1 : 3.96
CHEV 1	63.5	1 : 3.13	149.8	1 : 4.60

Maximum storey displacement and its ratio are tabulated in table 8. It has been observed that Inverted V model has showed lesser displacement compared to other models as per codal provisions.

Among Chevron models, Chev 0.25 has showed nearer values to Inverted V bracings within codal limits. Chev 0.25 model has showed 21%, 44% more displacement for RS X and RS Y cases with respect to Inverted V model. As the length of link beam increased, the storey displacement has increased can be observed. Chev 1m has showed maximum displacement compared to all models.

E. *VERTICAL DISPLACEMENT OF BEAM AT BRACE JOINT*

Figure 21: Vertical displacement of beam at brace joint



From the figure 21; it is observed that for RS X load case Chev 0.5 model has showed lesser vertical displacement of beam at braced point compared to Inverted V and other Chevron bracing systems. Maximum vertical displacement of beam is observed in Inverted V model compared to Chevron models. For RS Y load case, Chev 0.25 has showed lesser displacement compared to Inverted V bracing and other Chevron bracing systems.

F. *DRIFT INDEX RESULTS*

Drift index is the relative storey displacement between the two stories. In the considered models maximum drift has been observed at storey 2 which are tabulated below for RS X and RS Y load cases. The ratio of drift values of Inv V and Chevron models with different link beams are tabulated at table 9.

All the models have showed drift values as per codal limit i.e less than 0.004 times the storey height. Inverted V brace has showed less drift compared to Chevron bracing systems. Chevron with 0.25 link beam has showed 24% more drift compared with Inverted V bracing. Chevron of 1m link beam showed maximum drift index of 386 % & 500% more than Inverted V brace for RSX & RSY load cases respectively.

Table 9: The ratio of Drift Index of Inverted V and Chevron models for RS X& RSY

MODELS	RS X	RATIO	RS Y	RATIO
INV V	0.001324		0.001842	
CHEV 0.25	0.001647	1 : 1.24	0.003008	1 : 1.60
CHEV 0.5	0.002459	1 : 1.86	0.007089	1 : 3.85
CHEV 0.75	0.00371	1 : 2.80	0.010398	1 : 4.99
CHEV 1	0.005121	1 : 3.86	0.0121	1 : 5.12

RESULTS OF DIFFERENT BRACING PATTERN OF CHEVRON BRACING SYSTEM

G. Storey Displacement of Unbraced and Chevron models for Different Pattern of Brace Arrangement.

All the chevron models have showed the storey displacements within the limit as per IS code i.e, H/500.

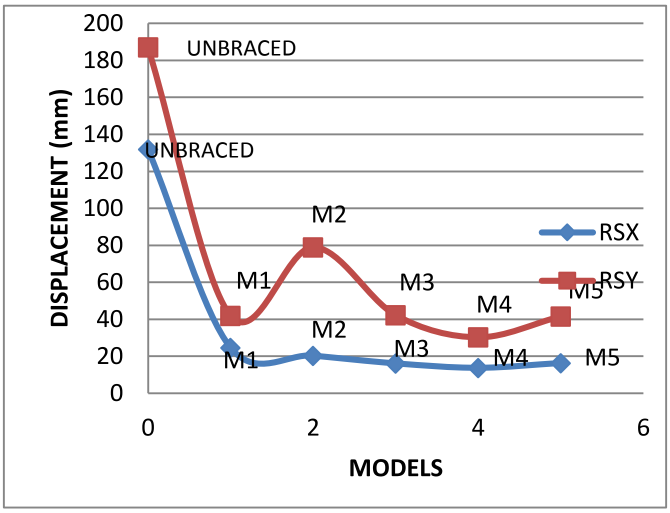
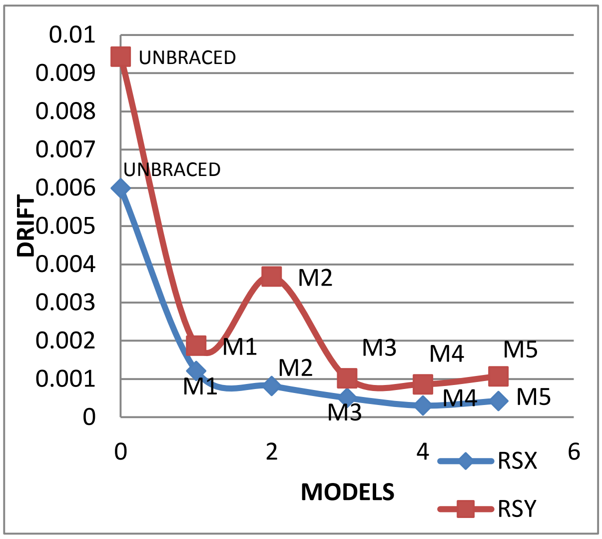


Figure 22: Storey Displacement of braced and unbraced models

Model 4 has showed minimum of 10% - 16% of displacement carried by Unbraced model. For RS X load case Model 1 has showed maximum displacement compared to other braced models. For RS Y load case Model 2 has showed maximum displacement compared to other braced models.

H. Storey Drift of Second Storey of All Models for RS X& RSY

Figure 23: Drift index of braced and unbraced models



From figure 23; For RS X load case, Model 1 has showed maximum drift and Model 4 has showed less drift compared to other braced models. In case of RS Y load, Model 2 has showed maximum drift and Model 4 has showed less drift compared to other braced models.

IV. CONCLUSION

Based on the outcomes of the analysis following conclusions are drawn:

1. Chevron brace carries about 89 – 91% of load taken by Inverted V brace.
2. In Inverted V brace compression brace buckles prior to Chevron brace.
3. The load transferred by Tension Brace to Beam has been reduced up to 9% in Chevron brace compared to Inverted V brace.
4. Chevron bracing with 0.25m link beam has showed better performance in all considered parameters compared to Chevron bracing with other link beams.
5. The Vertical displacement of beam at bracing point in Chevron bracing of 0.25m link beam has showed lesser displacement compared to Inverted V bracing system.
6. The Lateral Displacement and Drift Index values in Chevron bracing of 0.25m link beam are within the codal provisions and 21% more compared to Inverted V Bracings.
7. Even though Chevron brace has showed lesser stiffness compared to Inverted V brace, the chances of failure of beam is less in case of Chevron bracing system. Hence it can be conclude that Chevron brace with 0.25m link beam is considered as a better brace system compared to Inverted V brace.

8. The best patterns of arrangement of Chevron brace with 0.25m link beam is the Model 4 where Bracings are arranged alternatively in central bays with respect to storey has showed better performance compared to other pattern of bracing arrangements.

REFERENCE

[1] Roberto T. LEON, and Chuang-Sheng YANG, "*Special Inverted-V-Braced Frames With Suspended Zipper Struts*", **International work shop on steel and concrete composite construction, IWSCCC, Taipai,Taiwan-2003**

[2] Chuang-Sheng Yang,S.M.ASCE, Robert T.Leon, Reginald DesRoches, M.ASCE, "*Pushover Response of a Braced Frame with suspended Zipper Struts*", **Journal of Structural Engineering, Volume No 134, Issue No. 10, Oct-2008.**

[3] K.K.Sangle, K.M.Bajoria, V.Mhalungkar, "*Seismic Analysis of High Rise Steel Frame With And Without Bracing*", **15th World Conference on Earthquake Engineering, Lisbon, Portugal-2012.**

[4] M. N. Chimeh and P. Homami, "*Efficiency Of Bracing Systems For Seismic Rehabilitation Of Steel Structures*", **15th World Conference on Earthquake Engineering, Lisbon, Portugal-2012.**

[5] M.D. Kevadkar and P.B. Kodag, "*Lateral Analysis Of R.C.C Building*", **International Journal of Modern Engineering Research,Volume No.3, Issue No.3, PP-1428-1434, May-June 2013**

[6] Nathalie Robert and Robert Tremblay (2013), "*Seismic Design and Behavior of Chevron Steel Braced Frames*", **12th World Conference on Earthquake Engineering, Auckland, NewZealand, Jan –Feb 2013.**

[7] M.Pourbaba, M.Reza Bagerzadeh Karimi, B.Zarei and B.Bagheri Azar, "*Behavior of Zipper Braced Frame compared with other Concentrically Braced Frame*", **International Journal of Current Engineering and Technology, Volume No.3, Issue No.4, Septmber 2013.**

[8] M.Amini and M.Alirezaei, "*Response Evaluation of Braced Frames with Suspended Zipper Struts and Chevron Braced Frames in Near-Faultearthquake Ground Motions*", **American Journal of SustainableCities and Society, Volume No.1, Issue No2, Jan-Dec 2013.**

BIBILOGRAPHY

[1] **IS 800-2007**, "General construction in steel-code of practice" third revision, Bureau of Indian Standards, New Delhi, India.

[2] **IS 875 (Part 1 & 2)-1987**, "Code of Practice for Design Loads for Buildings and Structures", Bureau of Indian Standards, New Delhi, India.

[3] **"Earthquake Resistant Design of structures"**, Pankaj Agarwal and Manish Shirkhande, PHI Learning Pvt.ltd, ISBN-978-81-203-2892-1, 9th Edition, Aug-2011.

[4] **"Tall Building Structures: Analysis and Design"**, Bryan Stafford Smith and Alex Coull, ISBN-978-81-265-2986-6, 2013